Aerospace Technology Working Group

JPL

Theme: *Value that Space Programs bring to Humans*

Microgravity Instrumentation for Processing and Manufacturing

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A rose by any other name

- Processing
- Manufacturing
- Experimentation
- Measurement

- In space, aren t we talking about equivalent capabilities?

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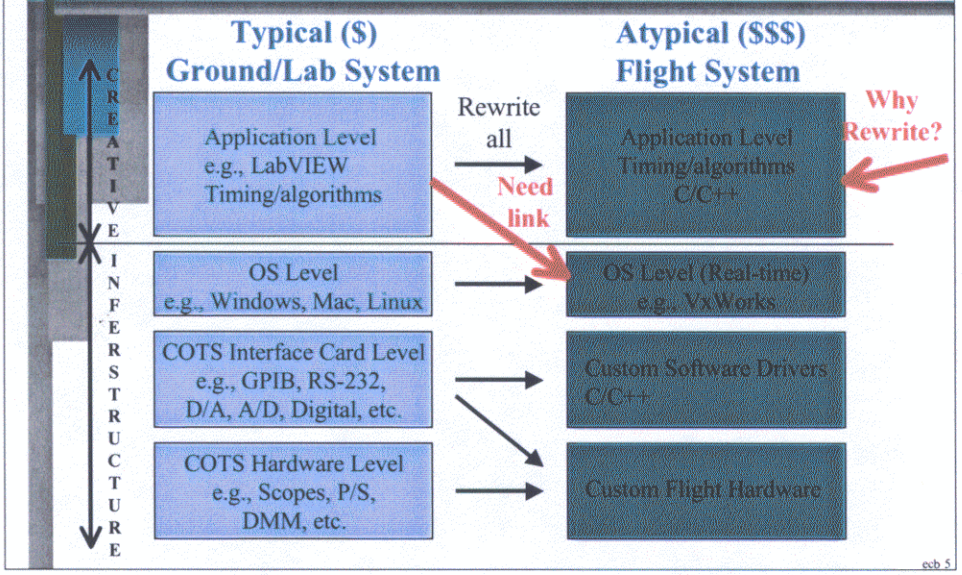
S/C Current Configuration

- VME Embedded Power PC Board
  - —flight-qualified
    - Rad hard, conduction cooled,
    - Temperature and materials tested
- Custom hardware boards (D/A, A/D, etc.)
  - —flight-qualified
- VxWorks real-time OS
- C or C++

What s Wrong With Current Configuration?

- Too expensive
- Not user-friendly
- Software written for the Lab needs to be rewritten for flight
  - —Many folks (experimenters, professors, scientists) are using LabVIEW on the ground to program the experiments
  - —Software rewritten in C/C++ is not readable by those same folks

Transition from Ground to Flight Systems



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Little and Big Questions?

- Can LabVIEW be used as flight software? Including all the requirements of flight software?
- Can software developed on the ground be transitioned to flight without having to rewrite it?
- How is ANY software flight-qualified?

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Plan

Approached National Instruments to develop a version of LabVIEW to run on VxWorks

—JPL-NI Technology Cooperation Agreement (TCA)

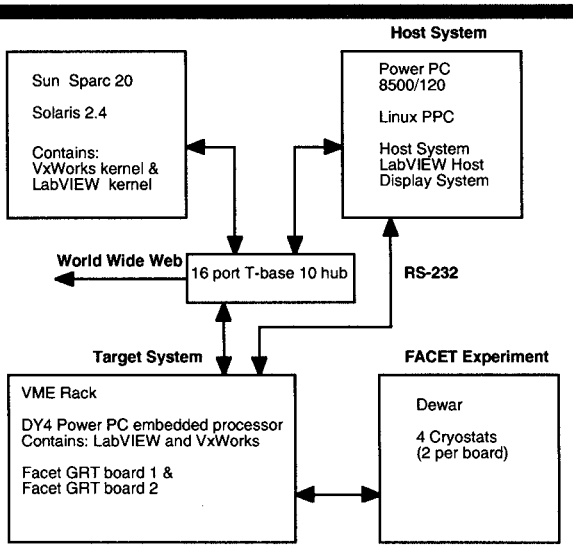
¥ Use processor specified by a current JPL space-station microgravity experiment (LTMPF)

—DY4 Power PC Board in a VME Chassis

¥ Use two custom (flight I/O) hardware boards developed by Ball and create drivers for boards in C

¥ Duplicate existing C (flight) software in LabVIEW

Schematic



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Results

- Ran experiment scripts
  - —Note: Debugged original (C/C++) software
- Simulated data and read it from boards
- Displayed it on another computer via internet
- Successful demo and New Technology Report

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What Now?

- Look into software qualification issues of LabVIEW
  - —Technology Infusion and Maturity Assessment (TIMA) Using Defect Detection and Prevention (DDP) Tools
- Find appropriate project
  - —PARCS
  - —AFE
- Have National Instruments optimize LabVIEW
  - —Timing
  - —Reduce footprint or memory size required
  - —Provide diagnostic tools
- Update TCA to transfer hardware and software to Ball Aerospace for further evaluation

TIMA Definition

- ¥ TIMA is a technology development and infusion planning exercise
- ¥ TIMA report is a product developed jointly by:
  - —Technology developer
  - —Small multidisciplinary team of experts in their respective fields
  - —Intended product customer
- ¥ Output of TIMA is used as guidance
- ¥ TIMA reports are controlled documents
- ¥ TIMA sessions should be treated as workshops
  - —Same concept as Team X/T but highly focused on technology issues
- ¥ TIMA uses the DDP tool (Code Q) as its engine

Workshop Objectives

- ¥ Investigate the feasibility of migration of LabVIEW software tools into critical flight applications
  - —Various Applications
    - ¥ MISTE, MISTE + , Autonomy
  - —Variety of issues
    - ¥ Reliability
    - ¥ Performance in a complex flight like system
    - ¥ Qualification
    - ¥ Configuration management
    - ¥ User interfaces
- ¥ Participants (primarily non-advocates)
  - — Flight Avionics Designers, System Engineers
  - — Quality and Mission Assurance, Flight Software Developers
  - — Integration and Test Engineers, Instrument Developers
  - — NI, Ball

Preliminary Findings

- General
  - —NI LabVIEW software tools may easily transition into flight applications for Shuttle and Station
  - —Tools show a promise to greatly reduce cost and schedule of software development, while increasing reliability
- Radiation Tolerance Issues
  - —Solution: embed under VxWorks, watchdog timers, separate source code, modular upgrades/uploads
- Real-time Control Issues
  - —Issues: max (#of loops X acq rate) =??, clock resolution, other timing and control issues
  - —Solution: Do experiments, a few loops will be easy

Preliminary Findings (cont.)

- Developmental
  - — Flight software, hardware, system engineers will need to work together early in the project life cycle
  - — Documentation standards do not exist and will need to be determined on a project by project basis
  - — Real time systems may require tighter timing and control than current capability
  - — Good existing libraries will be required
  - — Use available resource allocation tools along with some NI internal tools
  - — Develop processes and procedures for graphical programming
    - Hierarchal approaches, interconnectedness, code review, LabVIEW debugger utilization
  - — Leverage/push compatibility with other tools
    - E.g. Foresight, VxWorks, C++, Rhapsody

Primary Atomic Reference Clock in Space (PARCS)

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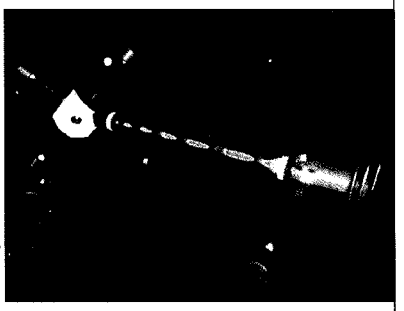
PARCS is an atomic-clock mission scheduled to fly on the International Space (ISS) in early 2005. The mission, funded by NASA, involves a laser-cooled cesium atomic clock, a high stability hydrogen-maser oscillator, and a time-transfer system using Global Positioning System (GPS) satellites.



The objectives of the mission are to:

- ¥ Test gravitational theory
- ¥Study laser-cooled atoms in microgravity
- ¥Improve the accuracy of timekeeping on earth

One Theory of Relativity prediction, made by Albert Einstein in 1915, is that clocks tick slower in strong gravity than they do in weak gravity.

The Space Station orbits at an altitude of 220 miles (360 kilometers), where gravity is slightly weaker than that found at the Earth's surface. Thus a clock aboard the Space Station ticks faster than a clock on the surface of the Earth by about 1 second in every 10000 years.

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Experiment Location

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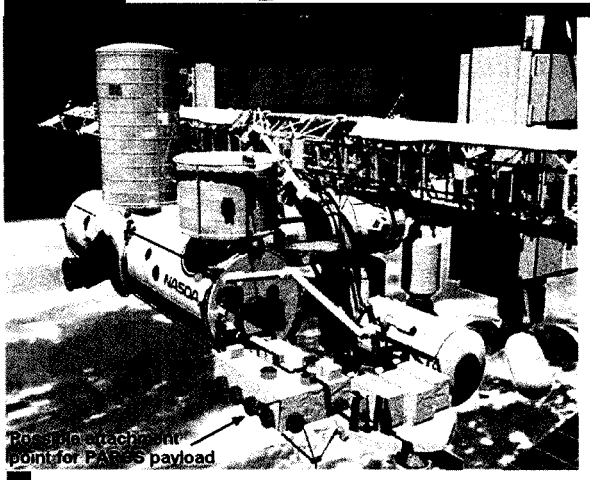

The preferred ISS location for the experiment is on the External Facility of the Japanese Experimental Module (JEM). This location affords good views of the GPS constellation of satellites, needed for comparing space and ground clocks. In addition, the volume, available power, and coolant system are well matched to the mission requirements

Web Sites:
http://funphysics.jpl.nasa.gov/technical/lcap/parcs.html
http://www.boulder.nist.gov/timefreq/cesium/parcs.htm

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Institutions and People

PARCS is a cooperative effort between the following organizations:

Institution	Contribution
Jet Propulsion Laboratory (JPL)	Flight Hardware Development
Harvard-Smithsonian Center for Astrophysics	Hydrogen Maser
National Institute of Standards and Technology (NIST)	Concept/Development Testing
University of Colorado	Gravitational Testing
University of Torino (Italy)	Atomic-Clock Microwave Cavities

Lute Malecki of JPL is the Project Scientist, and Dave Seidel of JPL is the Project Manager. The Co-Principle Investigators are Don Sullivan and Bill Phillips of NIST, and Neil Ashby of the University of Colorado.

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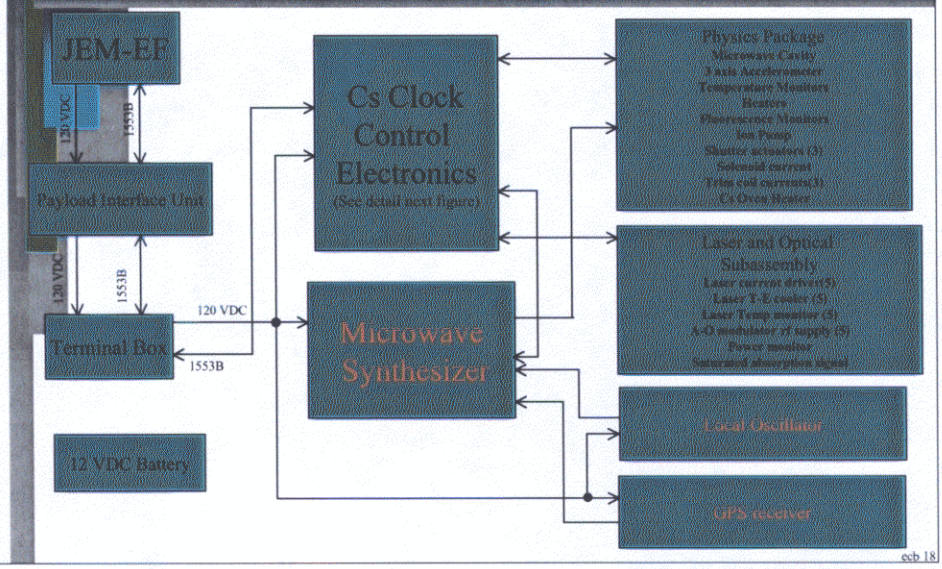
PARCS Electronics Block Diagram



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Avionics Flight Experiment (AFE) Introduction

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The AFE is a mature flight hardware developed for the X33 Program

The AFE has been qualified for X-33 orbital environment

Powered by a PPC603ev @ 200 MHz, its Real-Time OS (VxWorks) and software architecture is modular

- ¥ Originally used to test a suite of GPS receivers and MEMS inertial sensors, the AFE can be adapted to test other hardware components with RS-232 UART serial I/F
- ¥ External I/O to AFE via 1553B and 1773 (optical) I/F
- ¥ For test environment, terminal emulation I/F at the box
- ¥ 12 kg, 42 watts (@28vdc, with present sensor suites), 23x34x21 (cm^3 W/L/H)

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Present configuration

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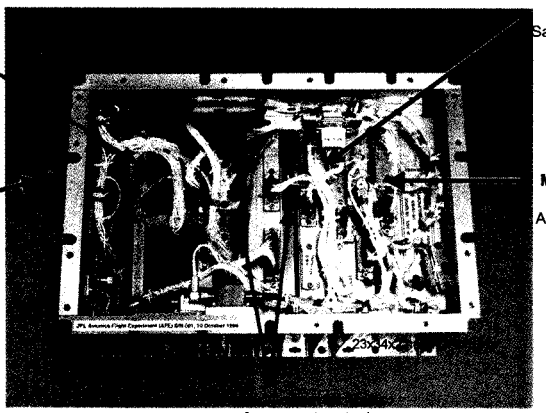
Stack:
00MHz
AM
3 v
sh Disk

GPS Receivers:
Ashtech G12,
Satloc SLXg (WAAS)



ternal I/O:
53B (6 A/B)
-1773 (A/B)
39 (2) serial
B25 serial
-28 VDC
- RF antenna

MEMS Sensors:
Gyros (3) &
Accelerometers (3)
(CSDL)

- for computer stack
- for sensor stack

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I/O specifications

FE, in its X-33 configuration, and has the following I/O limitations:

Fiber-optics AS-1773 I/O @20 Mbps, using 1553B protocol

1773 is the AFE cmd/tlm I/O to X-33 (via a VHM subsystem)

- ¥ AFE flight tlm is recorded on the X-33 VHM (for ops reasons)
- ¥ 1553B bus is for data eavesdropping ; AFE is not a 1553 RT
- ¥ Transmit function on AFE 1553 is intentionally disabled
- ¥ AFE inertial sensor (gyros and accels) UART is configured @ 19.2 Kbaud, 32-bytes packages @ 50 Hz (approx.)
- ¥ AFE is qualified for X-33 flight environment (thermal, vibration, and EMC/EMI); but is not radiation hardened

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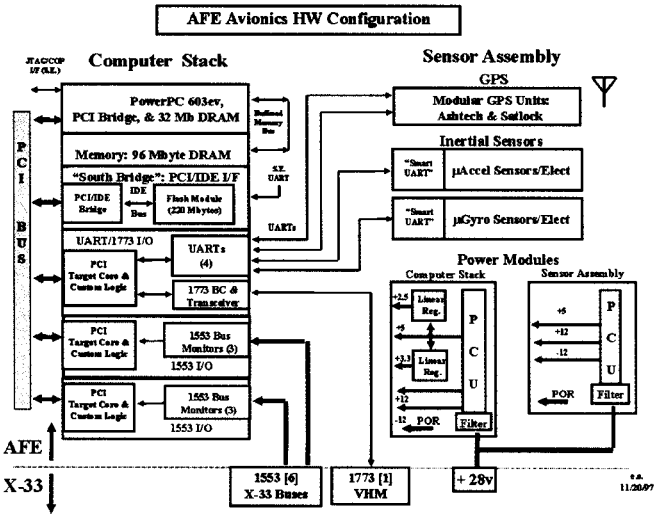
Functional Block Diagram



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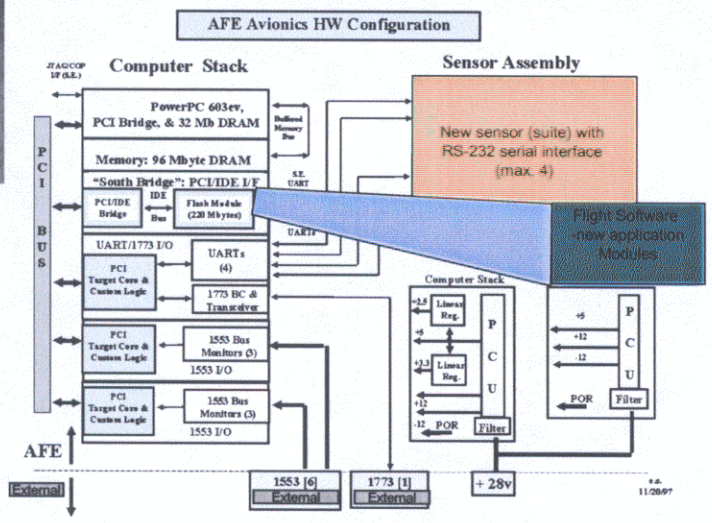
Functional Block Diagram (evolving)



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Summary

- Utilization of LabVIEW for flight software is doable
  - —Questions re: Flight qualification remain
- The AFE (Avionics Flight Experiment) is ready to be used as an evolving Testbed
  - —Testbed for new Sensor Suite
  - —Testbed for new flight software
  - —New Sensor Suite has to conform to existing electrical (power: +5 vdc, ±12 vdc), data (RS-232 19.2 or 9.6 Kbaud) I/O
  - —Physical dimension limited to existing footprint and height
  - —Larger suite can be accommodated via external box I/F
  - —AFE is self-contained and/or can interface with external via 1553 (6 A/B) and 1773 (A/B) I/O
  - —The AFE is ready for Flight Testbed for Rent

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